Expert Meeting on Ecosystem Accounts

5 - 7 December 2011, London, UK

ISSUE 3: Land cover mapping, land cover classifications, and accounting units

Land cover classification for ecosystem accounting

Prepared by Antonio di Gregorio (FAO), Gabriel Jaffrain (IGN-FI) and Jean-Louis Weber (EEA)

1. Introduction

Land cover is an observable image of the many processes taking place on the land surface. It reflects land occupation by various natural, modified or artificial systems, and to some extent the way land is used in such systems. Land cover cartographical and statistical information plays accordingly a central role in the description and quantification of economy-nature interaction:

Statistical units: The observation of land cover bio-physical characteristics supplies basic variables which inform ecosystem composition and structure. A first description of ecosystems can be done on the basis of this information.

Interactions: Because land cover can be observed in many ways, including by satellite or airborne remote-sensing, by area sampling or by censuses and administrative data, it makes the foundation of more comprehensive descriptions combining land cover and land use on the one hand and land cover and biological data on the other hand.

Localization: Land cover data are generally georeferenced with high accuracy in order to be used in geographical systems jointly with other data. Considering data which are collected with lower spatial resolution, land cover is frequently used as a proxy or as a tool to model spatial distribution of less accurate data. It is for example the case of statistics reallocated to a regular grid regarding the correlation between the observed phenomenon and a particular land cover class (e.g. population and urban fabric, trees and forests…).

Change monitoring: land cover change is a basis information taking stock of what has happed more than of emerging issues but it gives a fair and robust description of major processes such as urban development, extension of agriculture over marginal land or change in forest tree cover. The abundance images provided by of Earth observation satellites, the progress in open dissemination and access to image processing tool make land cover change or flow (in the sense of the SNA “other flows” which describe the “other change in volume” of non-financial assets) one of the basic ecosystem accounts.

2. Properties of land cover classification

These various capacities of land cover information help in framing the classification issue. Land cover classification has to:

- Capture the **main land cover classes needed for ecosystem accounting** at aggregated levels, relevant to national applications and international comparisons. These classes will have to qualify the observable geographical units used as statistical units in ecosystem accounting.
- Capture **main land cover change**, giving in particular the right focus to the description of those processes which reflect major economy-nature interaction, in particular the effects of change in land use.
- Contain the principles of its own **subdivision** which may be required for further consistent analysis and accounting at the subnational level and/or in specific biogeographical and/or climatic contexts. This is an important point considering the role of SEEA volume 2 to support ecosystem accounts experimentation.
- Be based on principles which provide the best **interoperability with other land cover classifications** used for specific thematic purposes (e.g. forest monitoring) or in national databases or in other international programmes.
- Be based on principles which allow the best **interoperability of land cover data with other geographical datasets** in the context of GIS and statistical databases. The issue is the facilitation of multi-thematic studies involving land use data (e.g. on farmers' and foresters' practices), socio-economic statistics (e.g on harvest) and the range of monitoring data.

In an abstract, ideal sense a classification system should exhibit the following properties:

- Use of consistent, unique and systematically applied classificatory principles.
- Adapted to fully describe the whole gamut of features types.
- The system is complete, providing total coverage of the world it describes.
- The classes derived from it are all unique, mutually exclusive and unambiguous.

In addition they should include some key characteristics to support evolving standards and in general the dynamic of science:

- Recognize the balancing act inherent in classifying (Bowker and Star, 1999).
- Render voice retrieval (Bowker and Star, 1999) by allowing users to detail and compare classes using the detailed class description (systematically organized with a list of explicit measurable diagnostic attributes), thus avoiding the risk of systems being impermeable to the end user.

3. The FAO LCCS (Land Cover Classification System)

LCCS The land cover classification for ecosystem accounting is established as an application of the geomatic rules adopted at the international level by ISO TC211 on the basis of the LCML (Land Cover Meta Language) developed by FAO. The purpose of LCML is to define a common reference structure for the comparison and integration of data for any generic Land Cover legends or nomenclatures.

In proposing LCML, FAO recognizes that there exist a number of land cover classification systems and nomenclatures in a number of countries and regions, and that these systems are well established and cannot be easily changed.

The LCML provides a general framework of rules from which more exclusive conditions can be derived to create specific L.C. legends or nomenclatures. It is a language based on physiognomy and stratification of both biotic and abiotic materials. The system may be used to specify any land cover feature anywhere in the world, using a set of independent diagnostic criteria that allow correlation with existing classifications and legends.

The FAO LCCS v.3 directly derived by the more general LCML allows describing any land cover at any scale by combining basic biophysical objects: grass, shrub, tree, rock, sand, snow, ice, water […]. Basic objects can be qualified according to their characteristics (e.g. type or size of a tree) and properties (e.g. natural grass vs. crop). Basic objects can be as well combined according to their spatial arrangement in the real world where they exist as geographical units which can be observed, mapped and analyzed as land systems. This is achieved in LCCS by combining objects according to rules defining vertical and horizontal patterns. With such approach, whatever land cover classification is documented in the same way, which makes possible precise translations which are necessary when analysis requires using several data sets, either different maps, or maps and statistics or maps and georeferenced data from monitoring systems when they contain land cover attributes. The choice made for SEEA land cover classification is in line with the development of open data bases giving access to huge resource.

In volume 1, a classification of land cover types has been adopted as the standard reference:

Table 1: Land cover types

Code	Title
01	**Artificial surfaces (including urban and associated areas)**
02	**Herbaceous crops**
03	**Woody crops**
04	**Multiple or layered crops**
05	**Grassland**
06	**Tree covered area**
07	**Mangroves**
08	**Shrub covered area**
09	**Shrubs and/or herbaceous vegetation aquatic or regularly flooded**
10	**Sparsely natural vegetated areas**
11	**Terrestrial barren land**
12	**Permanent snow and glaciers**
13	**Inland water bodies**
14	**Coastal water bodies and inter-tidal areas**

Source: http://unstats.un.org/unsd/envaccounting/seearev/Chapters/chapter5v4.pdf

4. LCCS and ecosystem accounts: first step: detailed land cover types

In SEEA volume 2, the classification process of land cover functional units for ecosystem accounting starts from the land cover types of volume1. **The first step** is a subdivision of land cover types in order to prepare the ground to the application needed for ecosystem accounting.

Table 2 Land Cover Types (all levels)

Code	Title
01	**Artificial surfaces (including urban and associated areas)**
01.a	Artificial surfaces from 10 to 50 %
01.b	Artificial surfaces from 51 to 100 %
02	**Herbaceous crops**
02.a	Small size fields of herbaceous crops rainfed
02.b	Small size fields of herbaceous crops irrigated or aquatic (rice)
02.c	Medium to large fields of herbaceous crops rainfed
02.d	Medium to large fields of herbaceous crops irrigated or aquatic (rice)
03	**Woody crops**
03.a	Small size fields of woody crops
03.b	Medium to large fields of woody crops
04	**Multiple or layered crops**
05	**Grassland**
05.a	Natural grassland
05.b	Improved grassland
06	**Tree covered area**
06.a	Tree covered area from 10 to 30-40 %
06.b	Tree covered area from 30-40 to 70 %
06.c	Tree covered area from 70 to 100 %
07	**Mangroves**
08	**Shrub covered area**
08.a	Shrub covered area from 10 to 60 % (open)
08.b	Shrub covered area from 60 to 100 % (closed)
09	**Shrubs and/or herbaceous vegetation aquatic or regularly flooded**
09.a	From 2 to 4 months
09.b	More than 4 months
10	**Sparsely natural vegetated areas**
11	**Terrestrial barren land**
11.a	Loose and shifting sand and/or dunes
11.b	Bare soil, gravels and rocks
12	**Permanent snow and glaciers**
13	**Inland water bodies**
14	**Coastal water bodies and inter-tidal areas**
14.a	Coastal water bodies (lagoons and/or estuaries)
14.b	Inter-tidal areas (coastal flats and coral reefs)

The basic rules for defining these land cover types are defined in table 3

Table 3 Land Cover Types Basic Rules

	Category	BASIC RULES
01	ARTIFICIAL SURFACES (INCLUDING URBAN AND ASSOCIATED AREAS)	The class is composed by any type of artificial surfaces. Additional characteristics for further break-down: Cover 01.a *(Cover from 10 to 50 %)* 01.b *(Cover from 50 to 100 %)*
02	HERBACEOUS CROPS	The class is constituted by a main layer of cultivated herbaceous plants. Additional characteristics for further break-down: Size of the field, Irrigation practice 02.a (*Size < 2 Ha rainfed)* *02.b (Size < 2 Ha irrigated or aquatic)* 02.c (*Size > 2 Ha rainfed)* *02.b (Size > 2 Ha irrigated or aquatic)*
03	WOODY CROPS	The class is constituted by a main layer of cultivated tree or shrub plants. Additional characteristics for further break-down: Size of the field 03.a (*Size < 2 Ha)* 03.b (*Size > 2 Ha)*
04	MULTIPLE OR LAYERED CROP	This class is constituted by at least two layers of cultivated woody and herbaceous plants or different layers of cultivated plants combined with natural vegetation.
05	GRASSLAND	The class is composed by a main layer of natural herbaceous vegetation with a cover from 10 to 100 %. Additional characteristics for further break-down: Natural (Unimproved), Improved 05.a *(Natural)* 05.b *(Improved)*
06	TREE COVERED AREA	The class is made of a main layer of natural trees with a cover from 10 to 100 %. Additional characteristics for further break-down: Cover 06.a *(Cover from 10 to 30-40 %)* 06.b *(Cover from 30-40 to 70 %)* 06.c *(Cover from 70 to 100 %)*
07	MANGROVES	The class is made of natural trees with a cover from

		10 to 100 % aquatic or regularly flooded in salt and brakish water.
08	SHRUB COVERED AREA	The class is composed by a main layer of natural shrubs with a cover from 10 to 100 %. Additional characteristics for further break-down: Cover 08.a *(Cover from 10 to 60 %)* 08.b *(Cover from 60 to 100 %)*
09	SHRUBS AND/OR HERBACEOUS VEGETATION AQUATIC OR REGULARLY FLOODED	The class is made of natural shrubs or herbs with a cover from 10 to 100 % aquatic or regularly flooded with water persistence from 2 to 12 months/year. Additional characteristics for further break-down: Water persistence 09.a *(Water persistence from 2 to 4 months)* 09.b *(Water persistence > 4 months)*
10	SPARSELY NATURAL VEGETATED AREAS	The class is made of any type of natural vegetation (all the growth forms) with a cover from 2 to 10 %.
11	TERRESTRIAL BARREN LAND	The class is made of abiotic natural surface. Additional characteristics for further break-down: type of abiotic surface 11.a *(Loose and shifting sand and/or dunes)* 11.b *(Bare soil, gravels and rocks)*
12	PERMANENT SNOW AND GLACIERS	This class is composed by any type of glacier and perennial snow with persistence of 12 months/year.
13	INLAND WATER BODIES	This class is composed by any type of inland water body with a water persistence of 12 months/year.
14	COASTAL WATER BODIES AND INTER-TIDAL AREAS	The class is made on the basis of geographical features in relation to the sea (lagoons and estuaries) and abiotic surfaces subject to the water persistence (inter-tidal variations). 14.a *Coastal water bodies (lagoons and/or estuaries)* 14.b *Inter-tidal areas (coastal flats and coral reefs)*

Source: FAO and EEA 21 July 2011 : Draft of land sections in the SEEA [vol.1] Chapter 5 "Asset accounts" Re-drafting of sections submitted to Global Consultation in May 2011[*],*

(Annex 1 presents explanatory notes of land cover type's classification.)

…

[*] Prepared by Jean-Louis Weber (EEA), Antonio Di Gregorio (FAO, NRL) and Valentina Ramaschiello (FAO, ESS)

5. Second step: definition of land cover flows and land cover functional units

a. Introduction

The second step is establishing a first sketch of land cover functional units on the basis of existing experience in land and ecosystem accounting. As previously agreed this classification should remain as simple as possible and contain circa 15 classes.

In order to achieve the highest result in the context of buoyant development of geographical databases driven by specific needs, LCCS defines a strict set of rules and a meta language to keep track in the classification of the primary observation and avoid risks of confusion when different sources are used in one particular application. For that purpose, the basic bio-physical objects and derived land cover types are scale-independent (a tree is a tree, whatever the scale…).

The “real world” to map is, however, covered by countless combinations of vegetal and abiotic objects more or less intensively managed. The common language describes accordingly geographical areas, named according to their natural vegetation (like forests, scrubland, heathland, grassland, cropland and marshes), or to natural absence of vegetation (sand, rocks, glaciers, water bodies) or their artificial character (built-up areas). Many situations are expressed as composite of mixed covers or landscape mosaics. The classification established for ecosystem accounting purposes will describe in a strict way how these geographical units are defined in terms of component objects, their characteristics and properties as well as of horizontal patterns of their spatial arrangements. This requires a choice regarding the scale where maps should be produced and/or the size of the minimum mapped unit, according to the ecosystem accounting purpose. Considerations relate to the minimum detail of the description required regarding ecosystem, the detection of major land cover change, the need of frequent updates and finally cost efficiency. From known experiences, a good compromise at continental to national scales is around the scales of 1/100 000 (e.g Corine land cover, AfriCover) to 1/250 000 (e.g. TerraNorte/Russia) or similar. Sub national to local studies require more detailed scales but can be usefully summarized at the recommended scale in view of comparisons and contextualization. Scales less detailed than 1/500 000 can produce fair description of stocks but change detection is very limited.

b. Land cover change and flows

The detail of the classes has to fit land cover change detection. For example, the important conversion in many countries of small field family agriculture towards large field intensively managed cannot be detected and recorded if agriculture is not subdivided into two classes reflecting the situation.

A study carried out by the EEA in Europe confirms that a very large proportion (more than 95%) of land cover change monitored by LEAC based on Corine 44 classes can be detected with a relatively aggregated classification of land cover of circa 15 classes.

The Classification of Land Cover Flows (LF) is derived from the classification defined and used in the Land and Ecosystem Accounts (LEAC) report of 2006.

Table 4 Provisional Land-cover Flow classification

lf1 Land development processes, urban sprawl, expansion of intensive land	
lf11	Artificial development over agriculture
lf12	Artificial development over forests
lf13	Artificial development of other natural land cover
lf14	Conversion from small field agriculture and pasture to broad pattern
lf15	Conversion from forest to agriculture
lf16	Conversion from marginal land to agriculture
lf17	Water body creation and management
lf2 Land restoration processes	
lf21	Conversion from crops to set aside, fallow land and pasture
lf22	Withdrawal of farming
lf23	Forest creation, afforestation of agriculture land
lf3 Rotations, natural processes and steady state	
lf31	Internal conversion of artificial surfaces
lf32	Internal conversion between agriculture crop types
lf33	Recent tree clearing and forest transition
lf34	Forest conversions and recruitment
lf35	Changes of land-cover due to natural and multiple causes
lf4 No observed land-cover change	

c. First sketch of aggregated LCFU classification

Table 5 presents a possible aggregated classification of land cover functional units.

The documentation of the 15 classes is not yet done but should present few difficulties because LCFU classes definition have taken into account the detailed land cover types of tables 2 and 3. This classification is therefore fully compatible with the land cover classification presented in the SEEA volume 1.

On the other hand, table 5 can be easily bridged with Corine Land Cover using the LCML translation of Corine produced by FAO. The translation of CLC has been done with the last version of LCCS (version 3) that is directly derived by the LCML (Land Cover Meta Language). The LCML provides a general framework of rules based on physiognomy and stratification of both biotic and abiotic elements that may be used to specify any land cover feature all over the world, thus making available a common reference for land cover classification systems.

This classification has been tested with the European database of land cover change and the 15 classes allow fair detection of land cover change at the 1/100 000 scale.

Table 5 First sketch of aggregated LCFU classification

01	Urban and associated developed areas
02	Medium to large fields rainfed herbaceous cropland
03	Medium to large fields irrigated herbaceous cropland
04	Permanent crops, agriculture plantations
05	Agriculture associations and mosaics
06	Pastures and natural grassland
07	Forest tree cover
08	Shrubland, bushland, heathland
09	Sparsely vegetated areas
10	Natural vegetation associations and mosaics
11	Barren land
12	Permanent snow and glaciers
13	Open wetlands
14	Inland water bodies
15	Coastal water bodies
16	Sea (per memory)

d. Definition of LCFU classes with LCCS 3 and adjustment of the first draft

It will be done once an agreement is reached on the LCFU classification.

6. Options for detailed LCFU levels

a. Several options

The approach to more detailed levels of LCFU classification requires a special discussion regarding ongoing activities at the international level, in particular within GEO-GEOSS which is open to support the implementation of ecosystem accounts.

A first option is to leave it to national governments or regional institutions. LCCS3 gives this possibility.

A second option is to keep the aggregated level and propose details for selected classes only. It could be the case for example of forest tree cover detailed by density classes.

A third option is to anticipate needs of coordinated regional developments and propose details on the basis of existing experience. This could be done in a further implementation step. As background reference, existing experience in mapping land cover units is presented in next paragraph.

b. Existing experience in mapping land cover units with LCCS

Table 6 presents the applications carried out either by FAO itself or by projects using the LCCS classification system.

[to be developed]

Table 6 Existing experience in mapping land cover units with LCCS

GLOBAL /REGIONAL DATABASES • GLC 2000 (global, year 2002) • GLOBCOVER (global, year 2008) • NALCMS (US, Canada, Mexico, year 2009) • Inducusch Himalaya(Afganistan, Pakistan, India, China, Nepal, Buthan, Myanmar, year 2008) **FULL NATIONAL DATABASES** • Albania (scale 1:100.000, year 2000) • Argentina (1:200.000, 2010) • Bulgaria (1:200.00, 2010)	**PARTIAL NATIONAL DATABASES** • Afghanistan (1:350.000, 2009) • Brazil (1:250.000) • China (1:350.000, 2009) • India (1:350.000, 2009) • Myanmar (1:350.000, 2009) • Pakistan (1:350.000, 2009) • Romania (1:50.000, 2004) **ONGOING NATIONAL DATABASES** • Afghanistan (1:100.000)

• Burundi (1:100.000, 2002) • Bhutan (1:350.000, 2009) • Cambodia (1:200.000, 2010) • Cuba (1:200.000, 2010) • DR of Congo (1:200.000, 2001) • Egypt (1:200.000; Nile Delta: 1:100.000, 1999. • Eritrea (1:200.000, 2000) • Kenya (1:200.000, 2002) • Kenya(update 1:100.000, 2011) • Libya (1:100.000, 2006) • Lebanon (1:50.000, 2011) • Moldova (1:100.000, 2005) • Nepal (1:350.000, 2009) • Oman (1:100.000) • Rwanda (1:100.000, 2001) • Senegal (1:100.000, 2008) • Seychelles (1:200.000) • Somalia (1:200.000, 2001) • Sudan (1:200.000, 1999) • Sudan, South (New update 1:50.000) • Tanzania (1:200.000, 2001) • Tunisia (1:200.000) • Uganda (1:100.000, 2002) • Uruguay (1:100.000, 2010) • Yemen (1:200.000, , 2003)	• China • Cambodia • Ethiopia (1:25.000) • Fouta Djallon Highlands (1:75.000) • Lao PDR • Sudan North (1:50.000) • Thailand • Viet Nam **OFFICIAL NATIONAL LEGEND TRANSLATION** • Afghanistan • Burkina Faso • Cambodia • China (Yunnan) • India • Lao PDR • Lebanon • Malaysia • Myanmar • New Zealand • South Africa • Thailand • Viet Nam

Source: FAO (A. Di Gregorio)

Table 7 presents the applications of Corine land cover steered by the EEA in Europe and out of Europe in various cooperation programmes (involving in particular IGN-FI).

Corine land cover now has over 25 years of history. In the mid-1980s the Directorate General for the Environment of the European Commission launched the implementation of a European land cover map as part of the development of the pilot European environmental geographical information system called **CORINE** for **CO**ordination de l'**IN**formation sur l'**E**nvironnement. Corine land cover was conceived as an infrastructure for sister programmes such as Corine Biotopes, CORINAIR, Corine Soil Erosion, Corine Coastal Erosion and Corine Water. The feasibility tests of Corine land cover were conducted in 10 European countries out of the EU12 of that time. On the basis of their positive conclusions, the implementation of the Corine map and database at the country started, the first country being Portugal. Since then, CORINE land cover has not ceased to extend, now involving countries with completely different bio-geographical conditions, from arctic and boreal regions to the Mediterranean region via Atlantic and continental zones.

Today 39 European and pan-European countries hold a reliable CORINE land cover database describing the present situation as well as the changes that take place on their own territory. The programme is steered by the European Environment Agency and carried over under the framework of GMES. Only at the EEA itself, CLC downloads are counted by thousands every single month – tens of thousands certainly since the first CLC1990. To this central service should be added the dissemination of their national datasets by the member countries themselves.

The report on "CORINE LAND COVER OUTSIDE OF EUROPE, Nomenclature adaptation to other bio-geographical regions, Studies & project from 1990 to 2010" is presented as background document. It shows how the Corine Land Cover methodology has been adapted to different countries in Africa, Central America and South America.

Table 7 Existing experience in mapping land cover units with Corine land cover

• EU27 (1/100 000 scale, most countries surveyed for 1990, 2000 and 2006, next update in 2012) Austria Belgium Bulgaria Cyprus Czech Republic	• OTHER EEA MEMBER COUNTRIES Iceland Liechtenstein Norway Switzerland Turkey

Denmark Estonia Finland France Germany Greece Hungary Ireland Italy Latvia Lithuania Luxembourg Malta Netherlands Poland Portugal Romania Slovakia Slovenia Spain Sweden United Kingdom	• WESTERN BALKANS COUNTRIES Albania Bosnia & Herzegovina Croatia FYR of Macedonia Kosovo Montenegro Serbia • OUT OF EUROPE Palestine Morocco Tunisia Central America/ Caraibe test areas (San Salvador, Guatemala, Honduras, Haiti, Republic Dominican) Columbia (Rio Magdalena basin) Burkina Faso French Overseas Departments (Guadeloupe, Martinique, Guyana, La Reunion) Gabon (feasibility study starting now)

Sources: Europe: EEA; Out of Europe: IGN-FI (G. Jaffrain)

Issues:

Question 1: Opinion on the aggregated LCFU classification?

Question 2: Need for more detailed LCFU classifications at regional levels ?

Question 3: Need for additional thematic classes (e.g. based on density) for forested cover, urban areas… ?

ANNEXES:

1. Overview on Land Cover Classifications and their interoperability. The FAO LCML (Land Cover Meta- Language) by Antonio Di Gregorio, U.N. FAO NRL division, Rome
2. Classifications' explanatory notes *(to be delivered later…)*
3. Bridging table with other classifications *(to be delivered later, main examples given in Outcome paper 19b for SEEA volume 1…)*
4. Links to background documents
    a. FAO: http://eea.eionet.europa.eu/Public/irc/eionet-circle/leac/library?l=/cube/land_cover/formalization_meaning/_EN_1.0_&a=d
    b. EEA/ETCSIA/IGN-FI: http://eea.eionet.europa.eu/Public/irc/eionet-circle/leac/library?l=/cube/land_cover/clc-out-of-europe/_EN_1.0_&a=d

Overview on Land Cover Classifications and their interoperability. The FAO LCML (Land Cover Meta- Language)

By

Antonio Di Gregorio

U.N. FAO NRL division, Rome

Introduction

Despite the great need of data harmonization there is a huge problem of compatibility and comparability between land cover (LC) products. Harmonization should be the process whereby differences among existing definitions of land characterization are identified, clarified and inconsistencies reduced. However, this is not the actual case, where current maps exist mostly as independent and incompatible data sets. This is mainly due to the poor compatibility of their classifications or legends, which are often an arcane 'black box' to anyone outside the immediate group involved in their preparation. Mapping is by its nature a local activity, so at one level it can be understood why there is a tendency to establish unique classification systems to fit local conditions; however, these incompatibilities make it difficult to aggregate broader regional and global data sets. In order to be able to integrate data from multiple sources there is a strong requirement for semantic interoperability.

Semantic interoperability is one of the major unsolved problems in the modern use of LC data. Uncertainty is an inescapable element in all types of geographical information because truth as a distinct and indubitable fact cannot exist in a derived representation. Information is always relative to context. However in some disciplines (like LC) the level of semantic vagueness and relative misuse of the data is far too high and there is risk entailed in its practical use in many applications. Diffuse use of Geographical Information Systems (GIS) and spatial analysis has further exacerbated this problem, creating a vicious circle of vagueness and ambiguity in the LC semantic that constantly propagates and is strengthened through the interoperability issues encountered in using different data sets.

LC is one of the most easily detectable indicators of human intervention on the land; therefore, information on LC is critical in any geographical database. In modern maps, LC has become a sort of 'boundary object' between different disciplines. This, on the one hand, enhances the intrinsic value of this information, but on the other hand, by enlarging the base of potential users, poses new challenges for its harmonization and correct use.

Any land surface is heterogeneous and the mapping standards to acquire, represent and generalize land characteristics are about as diverse as the land surface itself.

In addition, there has been an explosion of LC data sets in the world, coupled with the growing use of new technologies and the fast moving changes in how information can converge across previously disparate families of disciplines. Hence fostering discussions and reviews toward development of internationally agreed standards to characterize and classify LC is a crucial task to minimize current inadequacies and to respond to the requests and needs of the international community.

Characterization, Classification (legends) and Standards

To classify is a human activity. Classification is the means whereby we order knowledge. Our lives are surrounded with systems of classification, limned by standards, formats, etc. The oldest method to communicate knowledge is, no doubt, human language and conversation, where specific language elements or specialized terms are created to exchange particular types of information. A body of shared knowledge as a basis for communication is therefore part of most sciences, and historically we find ample evidence of specialized terminology, hierarchical thinking and classifications established within those disciplines. Each discipline has its own jargon.

Bjelland (2004: 2) propose two distinct classification processes, cognitive and logical.

> ”... in the cognitive sense, classification is concerned with how people conceptualize the world in the form of mental representation and operations. In the logical sense, classification is concerned with the definition of terms in order to concretise concepts. The main difference is that in the cognitive sense concepts are subjective and private, while in the logical sense concepts are public and hence made inter-subjectively available by intensional definitions. It appears that classification in the cognitive sense is the justification for classification in the logical sense. Research within cognitive science has repeatedly demonstrated that concepts in general are subjective and vague and liable to change both between individuals and over time within the

same individual. It is exactly the vagueness, instability and subjectivity of mental concepts that cognitive theories of classification attempt to explain and that logical theory attempts to overcome".

Categorization can be therefore be associated with cognitive process while classification as a social process can be linked to a logical classification process.

In the case of spatial information, classification is an abstract representation of features of the real world using classes or terms derived through a mental process. Sokal (1974) defines it as: "the ordering or arrangement of objects into groups or sets on the basis of their relationships", and Bowker and Star (1999) as: "a spatial temporal or spatio-temporal segmentation of the world". They define a 'classification system' as "a set of boxes (metaphorical or literal) into which things can be put in order to then do some kind of work bureaucratic or knowledge production".

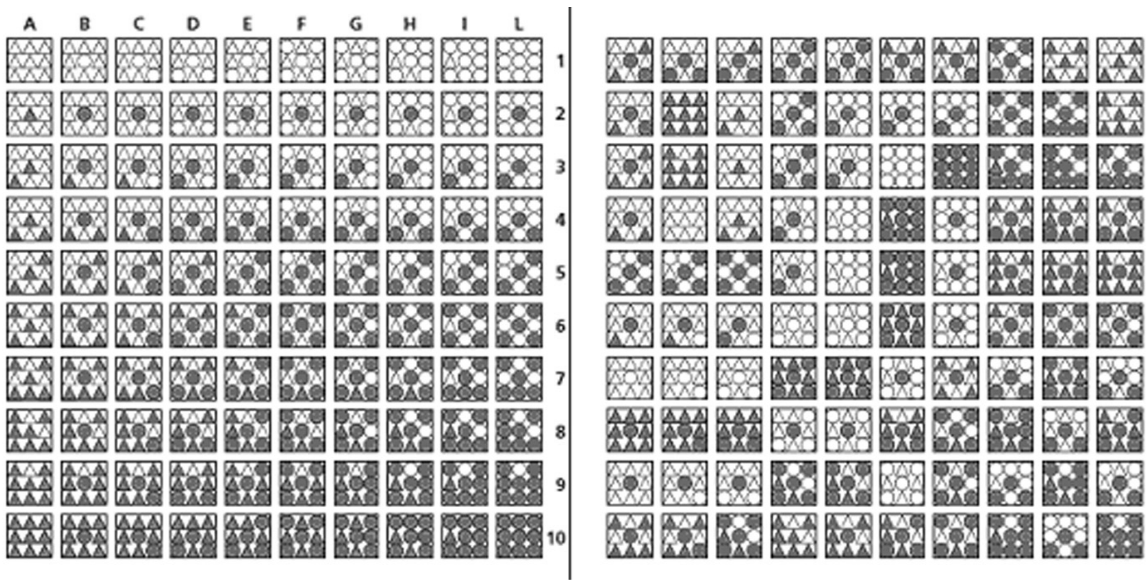

Figure 1. Abstract presentation of a classification consisting of a continuum with two gradients (left), in comparison with a concrete field situation (right). Triangle and circles represent the two elements being considered. Source: From Kuechler and Zonneveld, 1988.

In the case of spatial information, as for LC, a classification describes the systematic framework, with the names of the classes, the criteria used to distinguish them and the relationship between classes themselves. Classification thus requires the definition of class boundaries, which should be clear, precise, possibly quantitative and based upon objective criteria.

In an abstract, ideal sense a classification system should exhibit the following properties:

- Use of consistent, unique and systematically applied classificatory principles.
- Adapted to fully describe the whole gamut of features types.
- The system is complete, providing total coverage of the world it describes.
- The classes derived from it are all unique, mutually exclusive and unambiguous.

In addition they should include some key characteristics to support evolving standards and in general the dynamic of science:

- Be potentially applicable as a common reference system or be able to converse with other systems.
- Recognize the balancing act inherent in classifying (Bowker and Star, 1999).
- Render voice retrieval (Bowker and Star, 1999) by allowing users to detail and compare classes using the detailed class description (systematically organized with a list of explicit measurable diagnostic attributes), thus avoiding the risk of systems being impermeable to the end user.

Regarding LC, and in general disciplines producing 2-dimensional representations of a certain portion of the land, a classification is appears in a specific database in the form of legend. A legend can therefore be defined as the application of certain classification criteria (classification rules or classes) in a specific geographical area using a defined mapping scale and a specific data set. A legend may therefore contain only a proportion or sub-set of all possible classes of the reference classification system.

Shortcomings and problems of semantic interoperability with current systems

Categorization has always been a useful method to minimize the complexity of the real world. However, use of a single ontology system (a class name with class description) with a predefined list of categories implies important constraints that increase the fuzziness of the data and create huge interoperability problems:

Categories (classes) are usually limited in number. This forces the map producer to drastically generalize reality. Such generalization does not necessarily correspond to the needs of many studies, which ask for more and more detailed natural resources information. The resultant effect is an explosion in the number of classes, that can be unsystematic (an expansion of classes limited to only particular aspects of LC due to the specific needs of a particular project) and therefore difficult to manage in a GIS system

Generalization, as well as the creation of the class itself, is often an arbitrary process. Reality is a continuum, and any partition of the continuum into categories often reflect a specific need on the part of the data producer, and not necessarily reflecting the varied needs of individual end users. Threshold parameters, for instance, produce arbitrary and artificial differences in values in the real world

Class definitions are imprecise, ambiguous or absent. The build up of the definition in the form of a narrative text is unsystematic (many diagnostic criteria forming the system are not always applied in a consistent way) and in any case do not always reflect the full extent of the information.

Generalization into categories where meaning is very often limited to the class name, or has only an unclear class description, implies rigidity in the transfer of information from the data producer to the end user community. End users have limited if any possibility to interact with the data, and must therefore accept them 'as is'. The representation of the granularity of the aspects summarizing a specific feature of the real world is drastically reduced or lost. Often some vagueness in the class definition is artificially included by the map producer to hide some 'technical anomalies' when reproducing a certain feature on the map. Moreover, vagueness or extreme complexity in the class definition makes it difficult to correctly assess the accuracy of the data set.

Structure of a data with just a name and a corresponding separate text description make it very difficult to manage the data set with modern GIS techniques.

Semantic interoperability is actually the main challenge in Spatial Data Infrastructures (SDIs). Interoperability is defined as "the ability of systems to operate in conjunction on the exchange or re-use of available resources according to the intended use of their providers" (Kavouras and Kokla, 2002). In the case of 'semantic interoperability', we refer to the understanding of the 'meanings' of different classes and relations among concepts.

On these aspects, current classification and legends shows severe limitations that risk affecting the practical use of LC information. The list below shows the most common problems encountered when dealing with semantic interoperability of classification systems.

- Different terms used for concepts (Synonymy).
- Different understanding of homonymous concepts (Polysemy) (e.g. the various meanings of the term 'forest' for forestry environmental modelling).
- Different understandings of the relations among common concepts.
- Common instances across databases assigned to different concepts in different ontologies.
- Common instances allocated to a more general concept in one hierarchy than in other.
- Equivalent concepts formalized differently.
- Equivalent concepts explicated differently.

The FAO LCCS

In 1966, FAO made a contribution to solving this situation by starting to develop a new way to approach the problem. A new set of classification concepts were elaborated and were discussed and endorsed at the meeting of the International Africover Working Group on Classification and Legend (Senegal, July 1996) (Di Gregorio and Jansen, 1996, 1997a, b). The system was developed in collaboration with other international initiatives on classification of LC, such as the U.S. Federal Geographic Data Committee (FGCD) – Vegetation Subcommittee and Earth Cover Working Group (ECWG); the South African National Land Cover Database Project (Thompson, 1996); and the international Geosphere-Biosphere Programme (IGBP) - Data and information System (DIS) Land Cover Working Group and Land Use Land Cover Change (LUCC) Core Project.

After a test period in the FAO Africover project in 1997–1999, the first official release of LCCS (v.1) was published in 2000 (Di Gregorio and Jansen, 2000). A second version was developed based on international feedback involving a large global community, and published in 2005 (LCCS v.2) (Di Gregorio, 2005). A new version (LCCS3) is planned for release in 2011.

LCCS adheres to the concept that it is deemed as more important to standardize the attribute terminology rather than the final categories. LCCS works by creating a set of standard diagnostic attributes (called classifiers) to create or describe different LC classes. The classifiers act as standardized building blocks and can be combined to describe the more complex semantics of each LC class in any separate application ontology (classification system) (Ahlqvist, 2008).

The creation of or increase in detail in the conceptualization and description of an LC feature is not linked to a text description of the classifier but to the choice of clearly defined diagnostic attributes. Hence the emphasis is no longer on the class name but on the set of clearly quantifiable attributes. This follows the idea of a hybrid ontology approach, with standardized descriptors allowing for heterogeneous user conceptualization (Ahlqvist, 2008).

During the practical use of the LCCS through the years, there has been an unexpected trend in the utilization of the system by the international user community. In addition to the creation of specific legends for specific applications, the system has also been used as a reference bridging system to compare classes belonging to other existing classifications.

In 2003, FAO submitted the LCCS to ISO Technical Committee 211 on Geographic Information as a contribution toward establishing an international standard for LC classification systems. This was the first time that this ISO committee had addressed a standard for a particular community of interest within the general field of geographical information. All of its previous standards had been higher level or abstract standards that established rules for application schema, spatial schema or similar concepts. There was some initial difficulty in initiating the standardization activity due to this more specific focus. The result was that a standard was first developed to address classification systems in general (ISO 19144-1 Classification Systems) and then one to address LC (ISO 19144-2 Land Cover Meta Language).

The FAO LCML (Land Cover Meta-Language)

The purpose of LCML is to define a common reference structure for the comparison and integration of data for any generic Land Cover legends or momenclatures. The approach has been to define a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different land cover classification systems to be described. This will improve the harmonization and integration of spatial data sets defined using different land cover classifications and the legends or nomenclature developed from these systems and allow them to be compared and integrated.

In proposing LCML FAO recognizes that there exist a number of land cover classification systems and nomenclatures in a number of countries and regions, and that these systems are well established and cannot be easily changed. In fact, portions of these systems are set in law in some nations with respect to land use legislation. For example, the definition of wetland is of great importance in some nations because there is environmental legislation in many nations to protect wetlands. Yet the definition of wetland varies between jurisdictions, and there is a need to be able to compare this and other types of land cover object. A wide acceptance of an approach to handling the description of land cover depends upon its flexibility to accommodate nomenclatures derived from different systems.

The approach taken by FAO is to avoid specific limitations such as fixed value ranges for attributes and the use of specific definitions for classifiers to increase the acceptability to the international community. The Land Cover Meta Language (LCML) avoids complex definitions, prefixed ranges of values. It acts as a boundary object to bring the Land Cover community together to create a common understanding of land cover nomenclatures with the aim to produce global regional and national data sets able to be reconciled at different scales and detail level and geographic places.

The LCML provides a general framework of rules from which more exclusive conditions can be derived to create specific L.C. legends or momenclatures. It is a language based on physiognomy and stratification of both biotic and abiotic materials. The system may be used to specify any land cover feature anywhere in the world, using a set of independent diagnostic criteria that allow correlation with existing classifications and legends.

Land cover classes are defined by a combination of a set of land cover elements. These land cover meta-elements are divided in two categories "basic meta-elements" the elements that constitutes the main physiognomic aspects of biotic and abiotic cover features, for instance for biotic features trees, scrubs, herbaceous vegetation etc., and "meta-element properties" that further define the physiognomic/structural aspect of the basic objects.

Further definition of the land cover metaclasses may be achieved by adding the meta-element qualities. The qualities are of two types land cover *element characteristics* and land cover *class characteristics*. "LC_ClassCharacteristics" and

“LC_ElementCharacteristics” are defined as optional descriptive elements not directly related to the physiognomic/structural characterization of the land cover meta-element. “LC_ElementCharacteristics” may be applied to a single basic meta-element or to single or a group of meta-elements forming a strata. “LC_ClassCharacteristics” relate to a whole Land Cover class, defined as the combination of single or multiple strata of single or multiple basic meta-elements. The definition of these characteristics is informative, not normative. That is, other sets of characteristics may be added and used with the LCML basic elements.

The metalanguage generates mutually exclusive land cover classes, with specific rules to deal with the all functional elements of the language (basic meta-elements and properties) and the different strata.

All land covers may be accommodated in this highly flexible approach. The metalanguage can be used to describe different LC legends in terms of the same basic meta-elements, thus contributing towards data harmonization and standardization. Data defined using different nomenclatures can be used together with or fused with other data described according to a classification scheme which is also expressed in the metalanguage. By standardizing the principles and structure of a metalanguage it is possible to interwork with other application areas or other nomenclatures within an application area. This is similar to interworking between other geographic information systems that complies to the same feature cataloguing methodology but use different feature catalogues, although in this case the concept of features are constrained to that of a classification system that partitions the attribute space (range) of a discrete coverage. Different nomenclatures, which are legends of classes defined in accordance with the LCML system, may be used within multiple product specifications.

Conceptual basis

Definition adopted for land cover

The common integrated approach adopted by FAO defines land cover as the *observed (bio)physical cover on the earth’s surface*. Land cover is considered a geographically explicit feature that other disciplines may use as a geographical reference (e.g. for land use, climatic or ecological studies).

LCML basic principle

A given land cover class in a LC legend is defined by the instantiation of a land cover metaclass that has been formed by the combination of a set of independent land cover meta-elements.

Land Cover Classification System design criteria

Land cover metaclasses shall be defined by a set of land cover meta-elements as represented by the class LC_Element and its subtypes. Further definition of the land cover metaclasses may be achieved by adding land cover characteristics. "LC_ClassCharacteristic" and "LC_ElementCharacteristic" are defined as descriptive elements not directly related to the physiognomic/structural characterization of the land cover object.

Due to the heterogeneity of land cover metaclasses, certain design criteria have been applied.

All vegetated classes are derived from a consistent physiognomic structural conceptual approach that combines the basic meta-elements for growth form with their physiognomic properties Cover and Height and arrange them in strata. At any level specific characteristics can be added.

The non-vegetated metaclasses have a specular approach.

The basic elements of each of the two class groups constitute the main physiognomic aspects of biotic and abiotic cover features. For instance, for biotic classes: trees, scrubs, herbaceous vegetation etc., the "properties" that further define the physiognomic /structural aspect of the basic objects are mainly the horizontal and vertical arrangement of the basic meta-element cover and height. All these elements (or part of them) can be arranged in one or more layers or strata.

Further definition of the land cover classes may be achieved by adding land cover characteristics. Land cover characteristics are defined as descriptive elements not directly related to the physiognomic /structural characterization of the class. Land cover element characteristics relates or to the basic meta-element itself or to single or group of strata of related basic meta-elements. Land cover class characteristics relate to the whole final Land Cover metaclass, defined as the combination of single or multiple strata of single or multiple basic meta-elements.

This results in a land cover class defined by specific rules that govern the place and the functional position of all elements of the language as basic meta-elements and their properties, (land cover characteristics) and the different strata composition.

General rules for classification

The factors governing the concepts of classification of Vegetated and Non-Vegetated metaclass groups are:

◎◎the definition of "***appearance***" or physiognomic aspect of the basic meta-elements LC_Vegetation and LC_AbioticSurface

the definition of the "***horizontal***" and "***vertical***" arrangements of the meta-elements

the definition of the ***layering*** or ***strata***◎◎

The three main aspects are described in the following sub clauses.

Land cover meta-elements

The description of each of the land cover meta-elements, the subtypes is given in a specific glossary of land cover elements. The model also shows how the land cover elements may be combined to form strata and how these may be combined to form land cover metaclasses.

Horizontal and Vertical arrangement

Two properties are of primary importance to the meta-elements. These are the "cover" and the "height". Specifically:

- ***Cover*** is the percentage of the area covered by a layer of LC_Vegetation basic meta-elements.

- ***Height*** is the distance measured from the ground to the average top of an LC_Vegetation basic meta-element.

Layering

Several vegetated or non-vegetated basic meta-elements may be combined to form a layer or strata and these strata may be combined to form a metaclass. There is no limit to the number of strata. One or more layers can be further characterized by their *temporal* or vertical relationship.

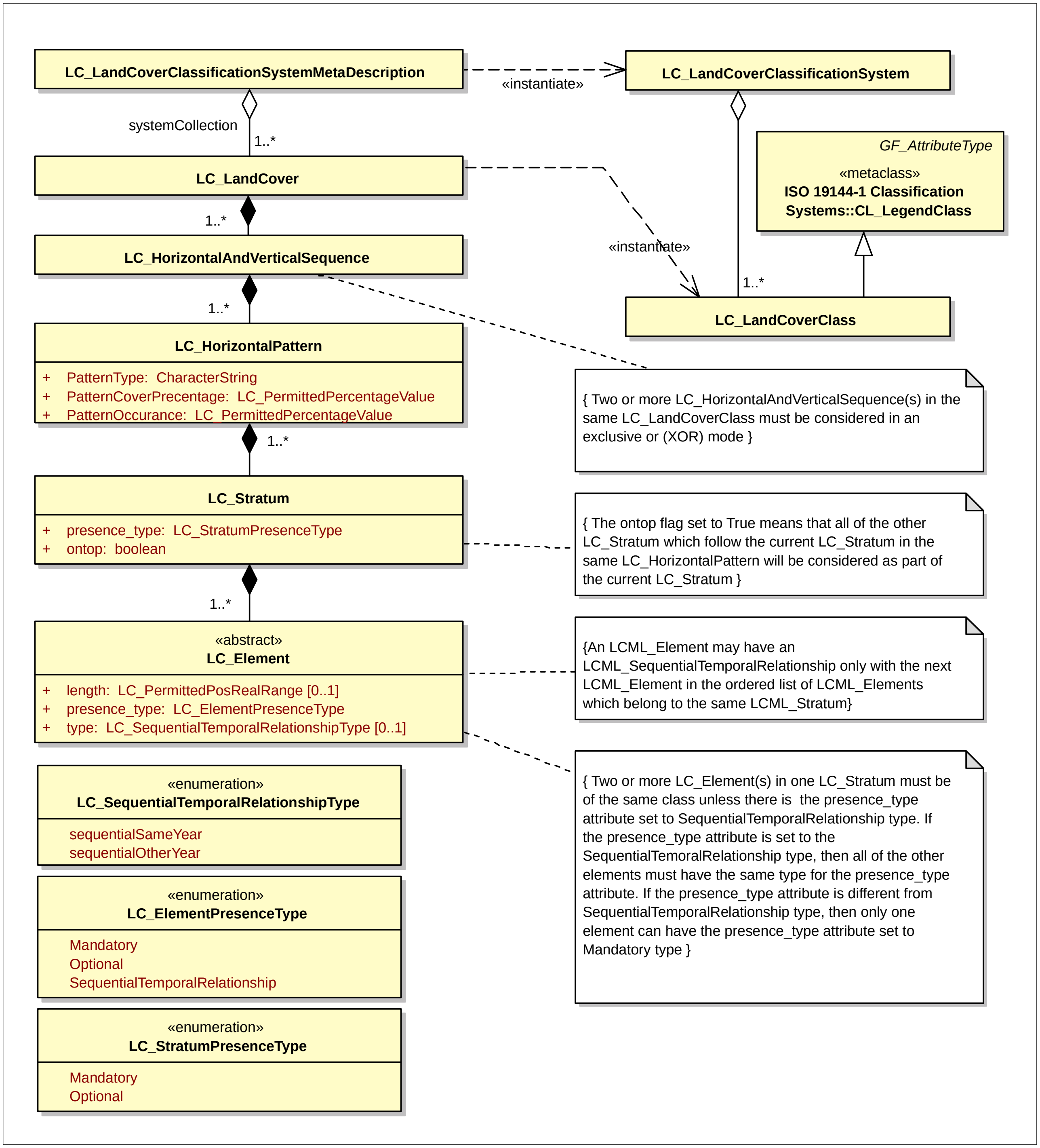

Figure 1 - High level structure of the Land Cover Classification Model

LC_LandCoverClassificationSystem metaobject and its components. This is represented in **Error! Reference source not found.**.

REFERENCES

Ahlqvist, O. 2008. In search of classification that supports the dynamics of science – The FAO Land Cover Classification System and proposed modifications. *Environment and Planning B: Planning and Design* 35(1) 169-1996.

Bjelland, T.K. 2004. Classification: assumptions and implications for conceptual modelling. Dissertation in Information Science. Department of Information Sciences and Media Studies, Faculty of Social Science, University of Bergen, Norway. 240 p.

Bowker, G.C. & Star, S.L. 1999. *Sorting Things Out: Classification and its Consequences*. MIT Press, Cambridge, MA, USA. 377 p.

Burley, Terence M., 1961; Land use or land utilization?: Prof. Geographer, v. 13, no..6, pa.18-20

Di Gregorio, A. & Jansen, L.J.M. 1996. FAO Land Cover Classification System: A Dichotomous, Modular-Hierarchical Approach. Paper presented at the Federal Geographic Data Committee Meeting – Vegetation Subcommittee and Earth Cover Working Group. Washington D.C., USA.

Di Gregorio, A. & Jansen, L.J.M. 1997a. Part I – Technical document on the Africover Land Cover Classification Scheme. pp. 4–33; 63–76, *in:* FAO Africover Land Cover Classification. *[FAO] Remote Sensing Centre Series*, No. 70. FAO, Rome 1997. 76 p.

Di Gregorio, A. & Jansen, L.J.M. 1997a. A new concept for a land cover classification system. Proceedings of the Earth Observation and Environmental Information 1997 Conference. Alexandria, Egypt, 13–16 October 1997.

Di Gregorio, A. & Jansen, L.J.M. 2000. Land Cover Classification System (LCCS). Classification concepts and user manual for software version 1.0. FAO, Rome. 179 p.

Sokal R. 1974. Classification: purposes, principles, progress, prospects. *Science*, 185(4157): 111–123.